

Dietary and inhalation  
exposure to  
**nano- and  
microplastic  
particles**  
and potential  
implications for  
human health



World Health  
Organization



Dietary and inhalation  
exposure to  
**nano- and  
microplastic  
particles**  
and potential  
implications for  
human health



**World Health  
Organization**

Dietary and inhalation exposure to nano- and microplastic particles and potential implications for human health

ISBN 978-92-4-005460-8 (electronic version)

ISBN 978-92-4-005461-5 (print version)

© World Health Organization 2022

Some rights reserved. This work is available under the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 IGO licence (CC BY-NC-SA 3.0 IGO; <https://creativecommons.org/licenses/by-nc-sa/3.0/igo>).

Under the terms of this licence, you may copy, redistribute and adapt the work for non-commercial purposes, provided the work is appropriately cited, as indicated below. In any use of this work, there should be no suggestion that WHO endorses any specific organization, products or services. The use of the WHO logo is not permitted. If you adapt the work, then you must license your work under the same or equivalent Creative Commons licence. If you create a translation of this work, you should add the following disclaimer along with the suggested citation: "This translation was not created by the World Health Organization (WHO). WHO is not responsible for the content or accuracy of this translation. The original English edition shall be the binding and authentic edition". Any mediation relating to disputes arising under the licence shall be conducted in accordance with the mediation rules of the World Intellectual Property Organization (<http://www.wipo.int/amc/en/mediation/rules/>).

**Suggested citation.** Dietary and inhalation exposure to nano- and microplastic particles and potential implications for human health. Geneva: World Health Organization; 2022. Licence: [CC BY-NC-SA 3.0 IGO](#).

**Cataloguing-in-Publication (CIP) data.** CIP data are available at <http://apps.who.int/iris>.

**Sales, rights and licensing.** To purchase WHO publications, see <http://apps.who.int/bookorders>. To submit requests for commercial use and queries on rights and licensing, see <https://www.who.int/copyright>.

**Third-party materials.** If you wish to reuse material from this work that is attributed to a third party, such as tables, figures or images, it is your responsibility to determine whether permission is needed for that reuse and to obtain permission from the copyright holder. The risk of claims resulting from infringement of any third-party-owned component in the work rests solely with the user.

**General disclaimers.** The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of WHO concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted and dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

The mention of specific companies or of certain manufacturers' products does not imply that they are endorsed or recommended by WHO in preference to others of a similar nature that are not mentioned. Errors and omissions excepted, the names of proprietary products are distinguished by initial capital letters.

All reasonable precautions have been taken by WHO to verify the information contained in this publication. However, the published material is being distributed without warranty of any kind, either expressed or implied. The responsibility for the interpretation and use of the material lies with the reader. In no event shall WHO be liable for damages arising from its use.

# CONTENTS

Acknowledgements	v
Abbreviations and acronyms	vii
Executive summary	viii
<b>1. Introduction</b>	<b>1</b>
1.1 Background and scope	1
1.2 Definitions	3
1.3 Composition and properties of particles	5
<b>2. Human exposure</b>	<b>13</b>
2.1 Occurrence in drinking-water	13
2.2 Occurrence in air	20
2.3 Dermal exposure	26
2.4 Occurrence in food	28
2.5 Summary and recommendations	43
<b>3. Observations from epidemiology</b>	<b>45</b>
3.1 Summary and recommendations	47
<b>4. Dosimetry and biokinetics</b>	<b>49</b>
4.1 Dosimetry: extrapolation from external to internal exposure	49
4.2 Biokinetics	57
4.3 Biokinetics: summary and recommendations	64
<b>5. Toxicological effects</b>	<b>67</b>
5.1 Literature review and experimental study evaluation	68
5.2 Nano- and microplastics as vectors of chemical exposure	84
5.3 Summary and recommendations	88
<b>6. Nano- and microplastics as vectors of pathogens</b>	<b>91</b>
6.1 Microplastic-associated biofilms in water	91
6.2 Microplastic-associated biofilms in food	93
<b>7. Summary and research topics</b>	<b>95</b>
7.1 Summary	95
7.2 Options for curbing exposure	98
7.3 Key messages and research topics	98
<b>References</b>	<b>101</b>
<b>Annex</b> Quality assurance and quality control scoring for studies reporting microplastic particles in air samples	<b>137</b>
<b>FIGURES</b>	
Fig. 1. Attributes of nano- and microplastics to be considered in assessing both exposure and hazard	6
Fig. 2. Classifications of manufactured and commonly encountered plastic materials	7

Fig. 3.	Concentrations of microplastic particles in drinking-water according to particle size in studies with a total assessment score $\geq 11$ and in which particles were verified as plastic	19
Fig.4.	Dietary consumption from 16 food categories derived from all 17 GEMS/Food clusters	40
Fig. 5.	Extrapolation of concentrations and doses of inhaled particles in the respiratory tract of rats to humans	50
Fig. 6.	Main regions of particle deposition in the human respiratory system and modelled deposition of a 1-g/cm <sup>3</sup> spherical particle in relation to the diameter of the particle	52
Fig. 7.	Approach used to evaluate studies of effects in vivo and in vitro for use in assessing human health risks due to exposure to nano- and microplastic particles	68
Fig. 8.	QA/QC evaluation scores for 76 studies in mammals in vivo	70
Fig. 9.	QA/QC evaluation scores for 76 studies in mammals in vivo exposed by ingestion or inhalation	70
Fig. 10.	QA/QC evaluation scores for 37 studies of effects in vitro	73
Fig. 11.	QA/QC evaluation scores for 37 studies of effects in vitro designed to reflect exposure by ingestion and by inhalation	81
Fig. 12.	Uptake and biokinetics that influence the effects on human health of exposure to nano- and microplastic particles	97

## TABLES

Table 1.	Average densities of commonly used polymers, the applications of representative additives and the estimated typical percentages added (weight/weight) of commonly used polymers	9
Table 2.	Recent studies on the numbers and characteristics of microplastic or microplastic-like particles in drinking-water	16
Table 3.	Studies with a total assessment score $> 10$ of microplastic particles in indoor and outdoor air at urban and rural sites	25
Table 4.	Reported numbers of microplastic or microplastic-like particles and particle characteristics in studies of their presence in food and beverages for human consumption	31
Table 5.	Estimated daily and annual per capita ingestion of microplastic particles	38
Table 6.	Criteria for evaluating the reliability and quality of in-vivo and in-vitro studies on the effects and biokinetics of nano- and microplastic particles	57
Table 7.	Experimental study design criteria related specifically to animal husbandry	76

## BOXES

Box 1.	Definitions of nano-, micro-, meso- and macro-plastic particles and related terms	4
Box 2.	Recommendations for improving sampling and analytical methods	14

# ACKNOWLEDGEMENTS

The World Health Organization expresses its appreciation to all those who contributed to the preparation and development of this report, including the colleagues named below.

This report is the product of several expert meetings held between 2019 and 2022, and represents a follow-up to the WHO report on Microplastics in Drinking Water, published in 2019.

## Lead authors

- Alan Boobis, Imperial College London, United Kingdom
- Flemming Cassee, National Institute for Public Health and the Environment, Netherlands
- Todd Gouin, Independent Consultant, United Kingdom
- Bart Koelmans, Wageningen University, Netherlands
- Shirley Price, University of Surrey, United Kingdom
- Sandra Wagner, German Federal Institute for Risk Assessment, Berlin, Germany
- Stephanie Wright, Imperial College London, United Kingdom

Experts who provided insights, wrote text, offered peer review, and/or participated in meetings:

- Guillaume Duflos, Agence Nationale de Sécurité Sanitaire de l'Alimentation, de l'Environnement et du Travail, France
- John Fawell, Cranfield University, United Kingdom
- Jennifer De France, WHO, Switzerland
- Bruce Gordon, WHO, Switzerland
- Matthias Labrenz, Leibniz-Institute for Baltic Sea Research, Germany
- Christine Lemieux, Health Canada, Canada
- Peter Marsden, Drinking Water Inspectorate, United Kingdom
- Lidia Morawska, Australia-China Centre for Air Quality Science and Management, Australia
- Maria Neria, WHO, Switzerland
- Sabine Pahl, University of Plymouth, United Kingdom
- Kim Petersen, WHO Switzerland
- Lisa Scheuermann, WHO, Switzerland
- Emanuela Testai, Istituto Superiore di Sanità, Italy
- Dick Vethaak, Deltares, The Netherlands
- Martin Wagner, Norwegian University of Science and Technology, Norway

- Annemarie van Wezel, University of Amsterdam, The Netherlands

The development and production of this document was coordinated and managed by Lisa Scheuermann and Kim Petersen (both WHO). Elisabeth Heseltine, France, edited the report.

WHO also gratefully acknowledges the financial support provided by the Ministry of Foreign Affairs, Norway.

预览已结束，完整报告链接和二维码如下：

[https://www.yunbaogao.cn/report/index/report?reportId=5\\_31645](https://www.yunbaogao.cn/report/index/report?reportId=5_31645)

